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Technical Report NAVTRAEQUIPCEN 82-C-0119-1

COMPUTER ASSISTED INSTRUCTION SYSTEM EFFECTIVENESS ON TROUBLESHOOTING TRAINING

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December 1983

FINAL REPORT SEPTEMBER 1982 - OCTOBER 1983

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The purpose of this study was to determine the performance effects of strategic troubleshooting computer assisted instruction (CAI) on troubleshooting behavior during performance tests on printed circuit boards. The study addressed whether or not supplementing the regular troubleshooting training curriculum with a CAI course would improve subsequent student performance over students who did not receive the additional instruction.

Subjects in the research were 54 Navy recruits in Electronic Technician

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training at the Basic Electricity and Electronics school at Orlando Naval Training Center. Students were classified as high, medium or low proficiency based on completion time of the previous self-paced course modules.

A two-way analysis of variance design was used for the independent variables of treatment condition (troubleshooting CAI versus control CAI versus control) and three student proficiency levels. The control CAI group received a BASIC programming course similar in length and presentation to the troubleshooting CAI to account for any Hawthorne effects resulting from the CAI treatment.

The dependent variables were number of test points probed, time to probe, and success rate on the first fault diagnosis. Additionally, the troubleshooting logic used by the students was extensively analyzed.

The results indicated that the troubleshooting CAI did not significantly improve performance; and, on a complex troubleshooting task, the control group performed significantly ($p < .05$) better than the troubleshooting CAI group. Analysis of the troubleshooting logic used indicated that all groups tended to use the strategies emphasized in training, but more from rote memory than from electronic theory. Final conclusions were that the troubleshooting CAI was not effective because it did not supplement the regular curriculum with required extra instruction.

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SECTION I

INTRODUCTION

The training of maintenance skills is an issue of major concern to the military due to increases in the complexity of in-the-field hardware and the cost of training maintenance technicians. Effective maintenance training programs can facilitate full utilization of hardware technology and decrease the maintenance costs by reducing the number of technicians required, spare parts costs, and hardware down time. Traditionally, hands-on electronic maintenance training has utilized actual equipment trainers (AETs) to provide troubleshooting training to the component level. The primary objective of this training has been to develop and sustain applied skills and knowledge in basic electricity and electronics. The Basic Electricity and Electronics (BE&E) School, located at the Naval Training Center in Orlando, Florida, utilizes a computer managed course of instruction that employs hands-on maintenance training in conjunction with self-paced instructional texts to train basic troubleshooting concepts and skills.

A recent study conducted by McDonald & Associates, Inc. (McDonald, Waldrop, & White, 1982) at the BE&E School revealed that students did not always utilize optimum troubleshooting procedures. Efficient electronic troubleshooting requires isolation of the faulty component by taking readings at logical test points and using the information from those readings to determine the next logical test point. A review of the School's curriculum indicated that logical troubleshooting behavior was addressed, but not stressed, and as a result, students adopted many different combinations of troubleshooting strategy in actual hands-on performance tests. The combinations adopted did not always lead to optimum troubleshooting performance and many times resulted in inefficient test point probes.

The use of computer assisted instruction (CAI) that interfaces simultaneously with an interactive video can optimize the costs and time associated with maintenance skills training. Many of the benefits derived from CAI are directly applicable to a maintenance training program like the one currently used at BE&E. CAI can provide practices, reviews, and performance tests directly to the student, freeing the Learning Supervisor (LS) to perform other instructional functions. Student performance can also be timed, evaluated, and remediated by the computer. Computer models, simulating actual equipment, reduce the number of AETs and circuit boards needed, thus reducing equipment costs. Test point probing and assignment of faulty circuits are done by computer, eliminating deadtime due to the servicing of damaged actual equipment and circuit boards. In addition, CAI allows the constant up-date of instructional information without costly text rewrites. CAI has the potential to provide optimum

individualized maintenance training, as well as to cut costs by managing the course curriculum.

To test the applicability of CAI to the BE&E School, a pilot study was conducted using an off-the-shelf computer/video assisted instructional program on strategic troubleshooting. The course emphasized taking a logical sequence of tests, based on both good and bad inputs and outputs, to localize the faulty component with the least number of testprobes. Twelve students participated in the study (four experimental and eight controls). Each experimental subject was matched with a male and female control subject. Results from the study indicated that the experimental subjects spent less time troubleshooting a faulty board, took fewer probes, and spent less time completing the BE&E Electronic Technician (ET) curriculum. Results from the pilot study were encouraging but difficult to generalize to the overall population, due to the small sample size. In order to determine whether or not the course was effective, further research was required utilizing a larger sample size, with appropriate control conditions.

Methods similar to those in the pilot study were used in the current research to implement the course just prior to students entering the ET Splice modules of BE&E School. The purpose of the study was to examine the effectiveness of the troubleshooting CAI course on troubleshooting behavior during performance tests in the ET Splice phase of instruction. The hypotheses to be tested were:

a. Students participating in the troubleshooting CAI will troubleshoot more efficiently than control students.

b. High proficiency students will troubleshoot more efficiently than medium and low proficiency students, and medium proficiency students will perform more efficiently than low proficiency students.

c. High proficiency students will complete the ET Splice curriculum in fewer hours than medium and low proficiency students, and medium proficiency students will complete the ET Splice curriculum in fewer hours than low proficiency students.

d. Students participating in the troubleshooting CAI will complete the ET Splice curriculum in fewer hours than control students.

SECTION II

METHOD

The primary objective of the research program was to determine the effects of the strategic troubleshooting course on student troubleshooting efficiency on a typical troubleshooting task of the ET Splice course. Since the purpose of the study was to determine the transfer of training of the troubleshooting CAI to actual hands-on performance, the research was designed to be integrated into the testing procedures used at the BE&E School. The CAI workbook and program were extensively modified to present the student with curriculum similar to that used at the BE&E School and to fulfill research data requirements. The BE&E School was used as a model since the results of this study were intended for use by curriculum designers of military electronics training with additional application to industrial training possible.

APPARATUS

STRATEGIC TROUBLESHOOTING COURSEWARE. The experimental treatment consisted of an off-the-shelf strategic troubleshooting course. This course combined videotape presentations, workbook exercises, and computer-assisted instruction (CAI) materials. The computer graphically presented hypothetical circuits with bad outputs and allowed the student to select test points and see the results of the tests. The computer provided feedback on whether or not a proper troubleshooting strategy was being used. The principal troubleshooting strategy taught by this course is the half-split technique, which involves successive testing of the midpoint between known good and bad signals until the fault is isolated. The program presentation time was a minimum of 9 hours, and additional time was required when students repeated units, reviewed practice problems, or required additional clarification.

BASIC COURSEWARE. A CAI/video program which taught the BASIC computer language was developed for use with the control subjects. The course was designed to be similar in length and instructional characteristics to the troubleshooting CAI, in order to make the course appear relevant to the control subjects, while avoiding any material which might be directly applicable to troubleshooting. The video portion entitled "Computer Programming: BASIC for Microcomputers" was made available from Educational Activities, Inc. and was integrated with a TRS-80 Model III BASIC computer interactive course.

CAI EQUIPMENT. Two TRS-80 Model III computers and 2 Betamax video playback units with video monitors were used to present the troubleshooting CAI. Headphones were utilized to prevent interference during simultaneous operation of the two stations. The treatment control CAI (BASIC course) utilized the same equipment as the troubleshooting CAI.

TROUBLESHOOTING EQUIPMENT. Since complexity of the troubleshooting task was certain to affect student behavior, 3 different printed circuit boards were utilized for the collection of actual troubleshooting performance data: a simple 205-5 Second IF Amplifier (Second IF), a medium complexity 205-4 First IF Amplifier (First IF) and a highly complex Power Supply (Power Supply) board with feedback loops. These boards were contained in a NIDA Model 205 Transceiver Trainer and a NIDA Model 201 Power Supply Trainer utilized as a normal part of the curriculum in the ET Splice course.

The study utilized 9 prefaulted boards for each of the 3 printed circuit board types, providing 27 prefaulted boards. Boards were prefaulted by the manufacturer. The 9 faulted boards for each board type were divided into 3 fault groups, based on fault difficulty. This allowed random assignment of faults to each student, to prevent the possibility of prior student knowledge of fault location and to reduce performance variance due to fault difficulty differences.

A total of 4 trainers (2 201 Power Supply Trainers and 2 205 Transceivers) were available, thus allowing any combination of 2 separate performance tests to be observed at one time. Additional troubleshooting equipment included: 2 sweep generators, 2 oscilloscopes, 2 Simpson Multimeters, and various probes. Any additional equipment required was supplied by the School, and equipment and circuit boards were maintained by the School.

SUBJECTS

Subjects were selected from students enrolled in the ET Splice program Modules 30 to 34 at the BE&E School. These modules are a preparatory course for an Electronic Technician rating. Students were male, E3 Seamen ranging in age from 17 to 35 with the average age being 19. The education level ranged from completion of high school to 1 year of college.

All students were tracked prior to entering ET Splice using the School's computer managed instruction (CMI) printouts. This allowed the researcher to predict when students would be entering ET Splice and ready to be assigned to 1 of the 3 treatment conditions.

Each student was assigned proficiency level of high, medium or low based on their actual elapsed time listed on the daily CMI printouts. This time represents a student's total contact time, accumulated from the time the student entered the BE&E curriculum to just prior to entering ET Splice.

Proficiency levels were hypothesized to significantly influence troubleshooting behavior. Student proficiency categories had been determined during previous research (McDonald, et.al., 1982) by looking at a random sample of 225 student BE&E School completion times. Proficiency categories were determined by monitoring completion times on BE&E CMI printouts and dividing the range of times into 3 equal groups of 75 each. This resulted in the following proficiency levels: high proficiency 0-224.99 hours, medium 225-289.99 hours, and low 290-365.99 hours. However, between the previous research and the current research, changes in the School's curriculum, physical layout, and student population resulted in a change in the time distribution of student hours. Using the same process and the existing categories as a base, new BE&E completion times were monitored, and the resulting categories used to reclassify student proficiency were: high less than 212 hours, medium 212-311.99 hours, and low 312-411.99 hours.

ET Splice students were randomly selected after being tracked through the CMI data and classified in 1 of the 3 proficiency levels. Six students from each of the 3 proficiency levels were assigned to 1 of the 3 treatment conditions. A total of 54 subjects were used in repeated measures across all 3 circuit board types (18 troubleshooting CAI, 18 control CAI, and 18 no-treatment controls).

Fifty-four students took a total of 162 performance tests across all 3 boards. A total of 54 performance tests (6 at each of the 3 proficiency levels on each of the 3 types of boards) were observed for each of the treatment conditions. Experimental matrices were used to assure that all treatment conditions were balanced and completely randomized. Student attrition occurred periodically due to equipment malfunction, student double-shifting because of transfer orders, or reclassification out of the ET Splice curriculum into an Electronics Warfare program. This had no effect on finishing the complete repeated measures since these students were replaced by others during the time set aside for data collection.

PROCEDURE

The equipment for the presentation of the troubleshooting CAI and control CAI conditions was set up at the Orlando Naval Training Equipment Center's Human Factors Laboratory. Two stations were available with only 1 type of treatment condition run at one time, i.e., 2 treatment control students or 2 experimental treatment students. Headphones were used to prevent the 2 stations from interfering with one another. A researcher was provided by the Human Factors Laboratory to monitor the 2 CAI training stations and to administer tests. Two stations were also set up at the BE&E School for collection of criterion performance data.

A pilot subject was sent to the Human Factors Laboratory to participate in the troubleshooting CAI. After completing the course, the student returned to the BE&E School and was observed on 1 Power Supply and 2 IF Amplifier performance tests. This preliminary data provided the on-site researcher with information on the CAI program timing, student acceptance of the CAI, and any possible BE&E curriculum interference. In addition, it allowed the researcher to begin tracking students at BE&E School, to assign proficiency levels and treatment conditions.

Students assigned to the troubleshooting CAI or control CAI were sent to the Human Factors Laboratory and told to report there for the next few days instead of reporting to BE&E School. These students were put on temporary hold on the School's CMI system so the 2 to 3 class days spent participating in the CAI treatment condition would not affect their class standing. After students completed their assigned CAI condition, they returned to BE&E and proceeded with their normal ET Splice curriculum. The LS sent all BE&E students to the research station when they were ready for performance tests on Module 30-2 (Power Supply) or Module 31-3 (Transceiver). This allowed the researcher to observe performance tests from the students who participated in the CAI courses, as well as to randomly select no-treatment control students. Eighteen troubleshooting CAI students, 18 control CAI, and 18 no-treatment control students were observed at the researcher's station. Three performance tests were observed for every student, 1 on the Power Supply, 1 on the First IF Amplifier and 1 on the Second IF Amplifier, totalling 162 performance tests. A prefaulted circuit board was randomly selected from the appropriate fault difficulty group for each student by the researcher before each performance test.

The ET Splice curriculum is a self-paced program. Students participating in the research program took their performance tests in normal sequence, without affecting their normal course workload or hours. The only modification was that 3 of their performance tests were taken at the research station using a circuit board which was assigned by the researcher, rather than by an LS. The ET Splice curriculum utilizes 3 different trainers, administering 7 practice exercises and 7 performance tests, on 7 different printed circuit boards. The research data collected represents 3 performance tests on 2 of the 3 trainers. The average ET Splice completion time is 60 classroom hours, and the typical class day runs 6 hours.

Before taking performance tests, students were briefed and assured that data collected would not affect their class standing. Students used the School's Troubleshooting Performance Response Sheets when taking the performance tests. The student informed the researcher when the fault was diagnosed. The student then took the response sheet to the LS for feedback on whether or not the diagnosis was

correct. If incorrect, the student returned to the research station to continue troubleshooting the same faulty circuit until the correct fault was diagnosed. After the correct fault was diagnosed, the student returned the completed response sheet to the researcher. If the performance test was on the Power Supply, the students returned to the regular BE&E curriculum until Module 31-3 when they were again referred by the LS to the research station. Prefaulted circuit boards on the NIDA 205 trainer were issued in random sequence; thus, students could receive either a faulty First IF Amplifier or a faulty Second IF Amplifier as their first 205 trainer fault card and could receive the remaining one as their second performance test measure. Students filled out response sheets for every performance test taken and again went to the LS for feedback on their fault diagnosis. All response sheets were returned to the researcher after the correct fault was diagnosed.

After students completed all 3 performance tests at the researcher's testing area, their daily progress at the School was monitored on the CMI to obtain student response histories after they completed the final BE&E School test. Student response histories provided the researcher with each student's total BE&E School completion time.

During the 3 performance tests taken at the research station by each of the 54 students, the researcher recorded the dependent performance measures of: specific test points taken, total number of probes, total probe time, fault diagnosed, student comments, number of trips to the LS and any additional relevant data. The 162 performance tests represent the criterion measure to determine any transfer of training effects from the experimental treatment to actual hands-on performance tests and any effect on troubleshooting behavior due to proficiency level. In addition, each student's overall BE&E course completion time was analyzed to determine any effect due to treatment or proficiency level. Data from these analyses are discussed in detail in the Results section.

EXPERIMENTAL DESIGN

The two-dimensional design matrix was a 3 (Treatment Condition) by 3 (Proficiency Level) design with 3 replications across circuit boards. The main independent variables were the treatment conditions (experimental treatment, treatment control and baseline control). Proficiency level was used as a blocking variable, assigning subjects to 1 of 3 predetermined categories (blocks) according to each individual's total number of hours in the BE&E curriculum prior to ET Splice. Assigning a specific number of subjects from each proficiency level to each treatment removes a large source of potential variation that might have occurred had proficiency levels been assigned randomly to treatment conditions. Fault groups and proficiency levels were

matched across all 3 treatment conditions to diminish the effects of extraneous variance and control for individual differences.

The experimental design studied the effects of the troubleshooting CAI course versus two types of control groups. The treatment control group was employed to account for any Hawthorne effect on student performance which might result from changes in the student's normal instructional environment. The treatment control manipulated the student's environment and the sequence of learning so that stimulus conditions closely corresponded to those of the experimental treatment group (troubleshooting CAI). The baseline (no-treatment) control group was used to compare the effects of the troubleshooting CAI against the regular class curriculum, as well as to examine the possible Hawthorne effects of removing the student from the BE&E environment. The matrix represents an independent design in that a group of students experience only one treatment condition across all 3 boards. The experimental design is represented in Figure 1.

The dependent variables under study were probe time, number of test points probed, correctness on first fault diagnosis, and total number of hours to finish BE&E School. In addition to analysis on the main dependent variables, the troubleshooting logic used by students was examined. All data were collected on 3 performance tests taken by each student on the 3 circuit boards. Analysis of these data indicated the degree of transfer of training from the treatment conditions.

A two-way Analysis of Variance (ANOVA) procedure was used to analyze the main effects of the design matrix (Ferguson, 1976), replicated across the 3 circuit board types. This analysis allowed the simultaneous examination of both the independent and combined effects of treatment conditions and proficiency levels. Each student was classified in 1 proficiency level and exposed to 1 set of experimental conditions across all 3 boards. However, since the effect of differences between the 3 board types was not a primary research question, the boards were analyzed as independent designs. The 2 CAI treatment conditions (experimental and control) were examined for any variability in troubleshooting performance when compared to the no-treatment control group.

Dichotomous data were analyzed using a Chi-Square test (Siegel, 1956). These data included whether or not the student was correct on the first fault diagnosis attempt and the number of troubleshooting strategies used prior to the first fault diagnosis. This analysis allowed examination of the frequency of correctness on first fault diagnosis and number of strategies used, between the treatment conditions. In addition, Chi-Square procedures were used to compare success of Half-Split troubleshooting procedure versus all other strategies combined on the first fault diagnosis.

TREATMENT CONDITIONS	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI			
Control (BASIC) CAI			
No-Treatment Control			

Figure 1. Experimental design matrix.

Analysis of Variance procedures were used to look at differences between treatment conditions. The level for significant difference was .05, i.e., there must be a 95% probability that the difference is not due to chance. Analysis of Variance procedures only indicated that there were significant differences between independent variables. In order to ascertain where the significant differences were occurring, a Fisher Least Significant Difference (LSD) post hoc procedure (Wilkowitz, et al., 1976) was performed on all significant ANOVA F tests. This compared all possible paired means using the Mean Square Within as the population variance estimate. Again, the probability level for significance was .05.

SECTION III

RESULTS

ANALYSIS OF VARIANCE - MAIN EFFECTS

The results discussed in this section examine criterion performance differences between students in the experimental treatment, the control treatment and the no-treatment (baseline) control conditions. The primary measures of effectiveness were the number of probes and the time taken to locate the fault during fault isolation on the criterion boards. The experimental and control conditions were examined within the 3 board types and analyzed as separate ANOVA designs.

POWER SUPPLY BOARD. The ANOVA totals and summary data for number of points probed are shown in Tables 1 and 2. These data indicate a significant ($p<.05$) performance difference between treatment conditions. Student proficiency level, however, did not significantly affect the number of points probed.

The least significant difference (LSD) post hoc technique was applied to determine exactly which variable differences were significant. The LSD uses the smallest value which can be considered significant. This technique examines all the pair-wise mean differences within a variable (e.g., treatment conditions) to determine which difference is the source of significance. Table 3 contains the mean data for the treatment conditions. The LSD indicated a significant ($p<.05$) difference in the number of points probed between the baseline control group and the troubleshooting CAI group (experimental treatment), with the control group probing fewer points.

The ANOVA totals and summary data contained in Tables 4 and 5 indicated a significant ($p<.05$) effect due to treatment condition on the time taken to isolate the fault (probe time in minutes). Table 6 contains the mean probe time for the Power Supply board by treatment condition. The LSD post hoc analysis indicated that the baseline control group took significantly ($p<.05$) less time to locate the fault than the troubleshooting CAI group. Student proficiency level did not significantly affect the amount of time required to isolate the fault.

FIRST IF BOARD. The ANOVA totals and summary data for points probed on the First IF board are contained in Tables 7 and 8. The ANOVA results indicated a significant ($p<.05$) effect due to student proficiency level. Table 9 contains the mean number of points probed by proficiency level. The LSD post hoc analysis indicated a significant ($p<.05$) difference between high and medium proficiency students and between high and low proficiency students with the higher proficiency subjects probing fewer points. The treatment conditions did not have

TABLE 1. POWER SUPPLY BOARD - ANOVA TOTALS - NUMBER OF POINTS PROBED

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	183	502	349
Control CAI	303	173	389
Control	161	146	144

TABLE 2. POWER SUPPLY BOARD - ANOVA SUMMARY - NUMBER OF POINTS PROBED

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	1652.18	2	826.09	.54
Treatment	9997.06	2	4998.53	3.29*
Interaction	10803.16	4	2700.79	1.78
Error	68310.90	45	1518.02	
Total	90763.56	53		

NOTE: * $p<.05$

TABLE 3. POWER SUPPLY BOARD - TREATMENT CONDITION - MEAN POINTS PROBED

TREATMENT CONDITION	MEAN POINTS PROBED
Troubleshooting CAI	57.44
Control CAI	48.06
Control	25.06

TABLE 4. POWER SUPPLY BOARD - ANOVA TOTALS - PROBE TIME (MINUTES)

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	360	374	401
Control CAI	324	265	401
Control	199	183	234

TABLE 5. POWER SUPPLY BOARD - ANOVA SUMMARY - PROBE TIME (MINUTES)

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	1350.52	2	675.26	.64
Treatment	7967.82	2	3983.91	3.78*
Interaction	571.36	4	142.84	.14
Error	47432.25	45	1054.05	
Total	57322.15	53		

NOTE: *p<.05

TABLE 6. POWER SUPPLY BOARD - TREATMENT CONDITION - MEAN PROBE TIME (MINUTES)

TREATMENT CONDITION	MEAN TIME
Troubleshooting CAI	63.06
Control CAI	55.00
Control	34.22

TABLE 7. FIRST IF BOARD - ANOVA TOTALS - NUMBER OF POINTS PROBED

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	142	289	222
Control CAI	143	291	285
Control	88	156	195

TABLE 8. FIRST IF BOARD - ANOVA SUMMARY - NUMBER OF POINTS PROBED

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	4466.00	2	2233.00	3.72*
Treatment	2380.58	2	1190.29	1.98
Interaction	656.00	4	164.00	.27
Error	26984.70	45	599.66	
Total	34487.63	53		

NOTE: *p<.05

TABLE 9. FIRST IF BOARD - PROFICIENCY-MEAN POINTS PROBED

PROFICIENCY	MEAN POINTS PROBED
High	20.72
Medium	40.89
Low	39.00

a significant effect on the number of points probed on the First IF board.

Tables 10 and 11 contain the ANOVA totals and summary data for the probing time on the First IF board. The ANOVA results indicated no significant ($p<.05$) performance effects due to treatment conditions or proficiency levels on probe time.

SECOND IF BOARD. Tables 12 and 13 contain the ANOVA data for number of points probed on the Second IF board. These data indicate no significant effects due to treatment condition or proficiency level.

The ANOVA results on probe time on the Second IF board indicated a significant ($p<.05$) effect due to treatment condition (Tables 14 and 15). The LSD post hoc analysis indicated that the troubleshooting CAI group and the baseline control group required significantly ($p<.05$) less time to isolate the fault than the control (BASIC) CAI group (Table 16).

CHI-SQUARE ANALYSIS - TROUBLESHOOTING SUCCESS

One measure of the effectiveness of a student's troubleshooting performance is correct fault isolation on the first fault diagnosis attempt. If the training effects of the experimental treatment and control conditions were equal, then we would expect the number of students who had correctly diagnosed the fault on the first diagnosis attempt to be equal across conditions. Whether or not a student was correct on the first fault diagnosis is a dichotomous variable which can be analyzed using a Chi-Square test. This is a comparison of a set of observed frequencies (number correct on first diagnosis) with a set of expected frequencies (expected number correct). The results in this section examine the Chi-Square tests within the 3 board types.

POWER SUPPLY BOARD. Tables 17 and 18 contain the Chi-Square frequency data for treatment conditions and student proficiency levels. As the probabilities indicate, there were no significant frequency differences between the independent variables. The analysis indicates that the assigned treatment condition and student proficiency level had little effect on troubleshooting success. The success rate for the experimental condition was not different from the success rate of the control conditions.

FIRST IF BOARD. Table 19 contains the Chi-Square data by treatment condition and indicates no significant differences in success rate on the first fault diagnosis attempt. Student proficiency level, however, did have a significant ($p<.01$) effect on whether or not a student had a correct diagnosis on the fault diagnosis (Table 20). Further analysis indicated that the high proficiency students had significantly ($p<.01$) more correct first attempts than incorrect, significantly

TABLE 10. FIRST IF BOARD - ANOVA TOTALS - PROBE TIME (MINUTES)

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	189	250	252
Control CAI	111	267	288
Control	106	193	185

TABLE 11. FIRST IF BOARD - ANOVA SUMMARY - PROBE TIME (MINUTES)

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	3599.96	2	1799.98	2.25
Treatment	1418.44	2	709.22	.89
Interaction	715.24	4	178.81	.22
Error	35920.80	45	798.24	
Total	41654.29	53		

NOTE: No Significant Effects

TABLE 12. SECOND IF BOARD - ANOVA TOTALS - NUMBER OF POINTS PROBED

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	186	213	180
Control CAI	202	245	232
Control	118	117	181

TABLE 13. SECOND IF BOARD - ANOVA SUMMARY - NUMBER OF POINTS PROBED

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	234.38	2	117.19	.28
Treatment	1958.12	2	979.06	2.38
Interaction	478.88	4	119.72	.29
Error	18438.65	45	411.97	
Total	21210.07	53		

NOTE: No Significant Effects

TABLE 14. SECOND IF BOARD - ANOVA TOTALS - PROBE TIME (MINUTES)

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	176	154	127
Control CAI	198	344	204
Control	112	168	188

TABLE 15. SECOND IF BOARD - ANOVA SUMMARY - PROBE TIME (MINUTES)

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	1020.30	2	510.15	1.05
Treatment	2980.08	2	1490.04	3.05*
Interaction	1972.92	4	493.23	1.01
Error	21949.65	45	487.77	
Total	27923.05	53		

NOTE: $*p<.05$

TABLE 16. SECOND IF BOARD - TREATMENT CONDITION - MEAN PROBE TIME (MINUTES)

TREATMENT CONDITION	MEAN TIME
Troubleshooting CAI	25.39
Control CAI	41.44
Control	26.00

TABLE 17. POWER SUPPLY BOARD -
FIRST FAULT DIAGNOSIS ATTEMPT BY TREATMENT CONDITION

TREATMENT CONDITION	CORRECT FIRST ATTEMPT YES	CORRECT FIRST ATTEMPT NO
Troubleshooting CAI	10	8
Control CAI	12	6
Control	11	7

$\chi^2 = .47$
$p = .79$

TABLE 18. POWER SUPPLY BOARD -
FIRST FAULT DIAGNOSIS ATTEMPT BY PROFICIENCY LEVEL

PROFICIENCY LEVEL	CORRECT FIRST ATTEMPT YES	CORRECT FIRST ATTEMPT NO
High	13	5
Medium	10	8
Low	10	8

$\chi^2 = 1.40$
$p = .50$

TABLE 19. FIRST IF BOARD -
FIRST FAULT DIAGNOSIS ATTEMPT BY TREATMENT CONDITION

TREATMENT CONDITION	CORRECT FIRST ATTEMPT YES	CORRECT FIRST ATTEMPT NO
Troubleshooting CAI	11	7
Control CAI	9	9
Control	12	6

$\chi^2 = 1.07$
$p = .59$

TABLE 20. FIRST IF BOARD -
FIRST FAULT DIAGNOSIS ATTEMPT BY PROFICIENCY LEVEL

PROFICIENCY LEVEL	CORRECT FIRST ATTEMPT YES	CORRECT FIRST ATTEMPT NO
High	15	3
Medium	6	12
Low	11	7

$\chi^2 = 9.36$
$p < .01$

($p < .03$) fewer incorrect first attempts than the medium proficiency students, and significantly ($p < .05$) more correct first attempts than medium proficiency students.

SECOND IF BOARD. Tables 21 and 22 indicate that the Chi-Square analysis did not reveal any significant ($p < .05$) frequency differences due to treatment condition or proficiency level. The number of students correct and incorrect on the first diagnosis attempt was not affected by the independent variables.

DESCRIPTIVE ANALYSIS - TROUBLESHOOTING LOGIC

The objective of this portion of the analysis was to examine the troubleshooting logic used by the students, assess its effectiveness, and determine the effects of the independent variables on the logic used. In order to determine the troubleshooting strategy or logic used, the sequence of probes taken to isolate the fault was analyzed. Each strategy used was recorded and classified into one of the following categories:

a. HALF-SPLIT - The troubleshooter successively tests the midpoint between a known good and bad signal or voltage until the fault is located.

b. LINEAR I/O - The troubleshooter begins at the board input and tests the voltage or signal output of each circuit sequentially until the faulty circuit or stage is found.

c. LINEAR TRACING - The troubleshooter begins at the board input and tests voltage or signals sequentially until the fault is found.

d. LINEAR IN-CIRCUIT TRACING - After a particular circuit has been isolated by any method, the troubleshooter tests voltage or signals sequentially within the specific circuit until the fault is located.

e. RELIABILITY TESTING - The troubleshooter successively tests the least reliable untested component until the fault is found.

f. SYMPTOMATIC - The troubleshooter tests the circuit area or stage whose failure would cause the front panel symptoms observed.

g. RANDOM - The troubleshooter uses no logical sequence of tests.

TABLE 21. SECOND IF BOARD -
FIRST FAULT DIAGNOSIS ATTEMPT BY TREATMENT CONDITION

TREATMENT CONDITION	CORRECT FIRST ATTEMPT YES	NO
Troubleshooting CAI	11	7
Control CAI	10	8
Control	10	8

$\chi^2 = .15$
$p = .93$

TABLE 22. SECOND IF BOARD -
FIRST FAULT DIAGNOSIS ATTEMPT BY PROFICIENCY LEVEL

PROFICIENCY LEVEL	CORRECT FIRST ATTEMPT YES	NO
High	11	7
Medium	10	8
Low	10	8

$\chi^2 = .15$
$p = .93$

h. LINEAR COMPONENT CHECKING - The troubleshooter sequentially tests conductivity of components until a fault is located.

i. OTHER - The troubleshooter appears to use some logical technique, but the technique cannot be identified.

Many times the sequence of probes indicated that the students utilized more than one technique to isolate a fault. The number of strategies used and the sequence of strategies were recorded until the student's first attempt to classify the fault, i.e., the first trip to the LS with a fault judgement. This section details the analysis of troubleshooting strategies by board type.

POWER SUPPLY BOARD. The Half-Split technique was utilized by most students as their first strategy (Table 23). The number of students using Half-Split first is significantly ($p<.01$, Chi-Square test) greater than the number using other techniques first regardless of treatment condition. After using the Half-Split technique, students tended to try different techniques, such as Linear Component Checking and Random (Table 24).

Chi-Square tests were used to determine if the number of strategies used was affected by the independent variables or if the number of strategies used affected troubleshooting success. Table 25 contains the Chi-Square frequency data, by treatment conditions, for the number of students using 1 to 4 (or more) strategies prior to their first trip to the LS with a fault diagnosis. Several students in each condition used more than 4 strategies, but the majority of first fault diagnosis attempts occurred within 4 strategies. The analysis indicated that the number of strategies used was not affected by treatment condition. Table 26 contains the total number of strategies used prior to the first trip to the LS with a fault judgement, by treatment condition based on whether the first attempt resulted in a correct or incorrect diagnosis. The Chi-Square test indicated no significant frequency differences. Thus, the number of strategies used was not affected by treatment conditions and did not affect success on the first attempt at a diagnosis.

Since the Half-Split technique was the predominant method used, and the method under study, further analysis examined whether or not students who used it first were more successful on their first fault diagnosis than those who did not use Half-Split. The data contained in Table 27 indicate that when compared to all other strategies combined, the Half-Split technique did not produce more students correct on the first attempt.

FIRST IF BOARD. The Half-Split technique was the predominant ($p<.01$) first strategy used on the First IF board, regardless of treatment condition (Table 28). After the Half-Split, students tended to use

TABLE 23. FIRST TROUBLESHOOTING STRATEGY USED - POWER SUPPLY BOARD

STRATEGY	TOTAL STUDENTS	%	TROUBLESHOOTING CAI STUDENTS	%	CONTROL CAI STUDENTS	%	CONTROL STUDENTS	%
Half-Split	47	87.04	13	72.22	17	94.44	17	94.44
Linear I/O	1	1.85	0		0		1	5.56
Linear Tracing	0		0		0		0	
Linear In-Circuit Tracing	0		0		0		0	
Reliability Testing	0		0		0		0	
Symptomatic	1	1.85	0		1	5.56	0	
Random	2	3.70	2	11.11	0		0	
Linear Component Checking	0		0		0		0	
Other	3	5.56	3	16.67	0		0	

TABLE 24. SECOND, THIRD AND FOURTH STRATEGIES USED - POWER SUPPLY BOARD

STRATEGY	SECOND STRATEGY			THIRD STRATEGY			FOURTH STRATEGY		
	TS* CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS	TS CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS	TS CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS
Half-Split	2**	0	0	4	4	2	1	1	0
Linear I/O	0	1	0	0	0	0	0	0	0
Linear Tracing	0	0	2	0	0	0	0	0	1
Linear In-Circuit Tracing	1	1	0	0	0	0	0	1	0
Reliability Testing	2	1	1	0	0	1	1	0	0
Symptomatic	0	0	1	0	0	0	0	0	0
Random	1	4	1	3	1	1	0	1	0
Linear Component Checking	5	5	3	1	0	1	3	2	2
Other	1	0	3	0	1	0	0	0	1

* TS = Troubleshooting

** The total number of students is less because not all students utilized more than one strategy.

TABLE 25. POWER SUPPLY BOARD - NUMBER OF STUDENTS USING ONE TO FOUR STRATEGIES PRIOR TO FIRST FAULT DIAGNOSIS

	STUDENTS USING			
TREATMENT CONDITION	ONE STRATEGY	TWO STRATEGIES	THREE STRATEGIES	FOUR STRATEGIES*
Troubleshooting CAI	6	4	3	5
Control CAI	6	6	1	5
Control	7	6	1	4

$\chi^2 = 2.35$
$p = .88$
* Includes students using more than four strategies.

TABLE 26. POWER SUPPLY BOARD - SUCCESS RATE BASED ON TOTAL STRATEGIES USED PRIOR TO FIRST FAULT DIAGNOSIS

	TOTAL STRATEGIES USED	
TREATMENT CONDITION	CORRECT FIRST ATTEMPT	INCORRECT FIRST ATTEMPT
Troubleshooting CAI	32	16
Control CAI	29	16
Control	19	19

$\chi^2 = 2.81$
$p = .24$

TABLE 27. POWER SUPPLY BOARD - SUCCESS RATE OF FIRST DIAGNOSIS USING HALF-SPLIT FIRST VERSUS ALL OTHER STRATEGIES

	CORRECT FIRST ATTEMPT	
FIRST STRATEGY USED	YES	NO
Half-Split	28	19
All Other Strategies	5	2

$\chi^2 = .03$
$p = .85$

TABLE 28. FIRST TROUBLESHOOTING STRATEGY USED - FIRST IF BOARD

STRATEGY	TOTAL		TROUBLESHOOTING CAI		CONTROL CAI		CONTROL	
	STUDENTS	%	STUDENTS	%	STUDENTS	%	STUDENTS	%
Half-Split	52	96.30	18	100.00	17	94.44	17	94.44
Linear I/O	2	3.70	0		1	5.56	1	5.56
Linear Tracing	0		0		0		0	
Linear In-Circuit Tracing	0		0		0		0	
Reliability Testing	0		0		0		0	
Symptomatic	0		0		0		0	
Random	0		0		0		0	
Linear Component Checking	0		0		0		0	
Other	0		0		0		0	

Linear I/O as their second strategy, Linear Component Checking as the third strategy, with no predominant fourth strategy (Table 29).

A Chi-Square test was used to determine if treatment condition affected the number of strategies a student used prior to the first trip to the LS with a fault diagnosis. Data in Table 30 indicate that this was not the case. The total number of strategies used by all students in each condition did significantly ($p<.05$) affect success on the first trip to the LS (Table 31). Further analysis found significance between the control CAI group and the baseline control group on incorrect first attempts, i.e., the students in the baseline control group used significantly ($p<.01$) fewer strategies on incorrect first attempts than the control CAI group. The Half-Split technique did not significantly affect success on the first diagnosis attempt when compared to all other techniques (Table 32).

SECOND IF BOARD. The first troubleshooting strategy used on the Second IF board was predominantly the Half-Split technique (Table 33). The first technique used was not affected by treatment condition. The students tended to use Linear Component Checking as the preferred second strategy, Half-Split as the third strategy, with no preferred fourth strategy (Table 34).

The number of strategies used by each student, prior to the first attempted diagnosis, was not affected by treatment condition (Table 35) and did not affect the success rate of that first attempt (Table 36). The students using Half-Split as their first strategy were not more successful than students using all the other strategies combined (Table 37).

ET COURSE COMPLETION TIMES

The ET Splice course is self-paced, and one of the hypothesized effects of the troubleshooting CAI was to shorten the amount of time required to complete the subsequent ET Splice curriculum. Likewise, since the student proficiency level was based on the completion time of the prerequisite course, it was predicted that the high proficiency students would require less time to complete the course than medium and low proficiency students and that high proficiency students receiving the troubleshooting CAI would require less time than all other students.

Tables 38 and 39 contain the ANOVA totals and summary data for ET course completion times (in total course hours). The results indicate that both proficiency level and treatment condition had a significant ($p<.05$) effect on ET Splice course completion time, but they did not have a significant interaction. The mean completion times for students classified by each of the independent variables are shown in Tables 40 and 41. The LSD post hoc analysis indicated that high

TABLE 29. SECOND, THIRD AND FOURTH STRATEGIES USED - FIRST IF BOARD

STRATEGY	SECOND STRATEGY			THIRD STRATEGY			FOURTH STRATEGY		
	TS* CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS	TS CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS	TS CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS
Half-Split	0**	0	0	1	1	1	2	1	0
Linear I/O	9	12	10	1	0	0	1	0	0
Linear Tracing	0	0	0	0	0	0	0	0	0
Linear In-Circuit Tracing	1	0	0	0	1	1	1	0	0
Reliability Testing	2	1	2	1	0	0	0	1	0
Symptomatic	0	0	0	0	0	0	0	0	0
Random	0	1	1	1	1	0	0	0	0
Linear Component Checking	3	3	2	8	5	4	0	1	0
Other	1	0	0	1	2	0	0	1	0

* TS = Troubleshooting

** The total number of students is less because not all students utilized more than one strategy.

TABLE 30. FIRST IF BOARD - NUMBER OF STUDENTS USING ONE TO FOUR STRATEGIES PRIOR TO FIRST FAULT DIAGNOSIS

	STUDENTS USING			
TREATMENT CONDITION	ONE STRATEGY	TWO STRATEGIES	THREE STRATEGIES	FOUR STRATEGIES*
Troubleshooting CAI	2	4	8	4
Control CAI	1	7	6	4
Control	3	9	6	0

$\chi^2 = 7.30$
$p = .29$
* Includes students using more than four strategies.

TABLE 31. FIRST IF BOARD - SUCCESS RATE BASED ON TOTAL STRATEGIES USED PRIOR TO FIRST FAULT DIAGNOSIS

	TOTAL STRATEGIES USED	
TREATMENT CONDITION	CORRECT FIRST ATTEMPT	INCORRECT FIRST ATTEMPT
Troubleshooting CAI	28	29
Control CAI	20	32
Control	25	14

$\chi^2 = 5.86$
$p = .05$

TABLE 32. FIRST IF BOARD - SUCCESS RATE OF FIRST DIAGNOSIS USING HALF-SPLIT FIRST VERSUS ALL OTHER STRATEGIES

	CORRECT FIRST ATTEMPT	
FIRST STRATEGY USED	YES	NO
Half-Split	30	21
All Other Strategies	1	1

$\chi^2 = .23$
$p = .63$

TABLE 33. FIRST TROUBLESHOOTING STRATEGY USED - SECOND IF BOARD

STRATEGY	TOTAL STUDENTS	TOTAL %	TROUBLESHOOTING CAI STUDENTS	TROUBLESHOOTING CAI %	CONTROL CAI STUDENTS	CONTROL CAI %	CONTROL STUDENTS	CONTROL %
Half-Split	45	83.33	15	83.33	15	83.33	15	83.33
Linear I/O	5	9.26	1	5.56	3	16.67	1	5.56
Linear Tracing	0		0		0		0	
Linear In-Circuit Tracing	0		0		0		0	
Reliability Testing	0		0		0		0	
Symptomatic	4	7.41	2	11.11	0		2	11.11
Random	0		0		0		0	
Linear Component Checking	0		0		0		0	
Other	0		0		0		0	

TABLE 34. SECOND, THIRD AND FOURTH STRATEGIES USED - SECOND IF BOARD

STRATEGY	SECOND STRATEGY			THIRD STRATEGY			FOURTH STRATEGY		
	TS* CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS	TS CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS	TS CAI STUDENTS	CONTROL CAI STUDENTS	CONTROL STUDENTS
Half-Split	0**	2	1	3	4	2	2	0	0
Linear I/O	1	0	0	0	0	0	0	0	0
Linear Tracing	0	0	1	0	0	0	1	0	0
Linear In-Circuit Tracing	0	0	0	0	0	0	0	0	0
Reliability Testing	3	0	1	1	0	0	0	0	0
Symptomatic	0	3	0	0	0	0	0	0	0
Random	1	2	1	1	1	0	2	1	1
Linear Component Checking	6	7	6	1	0	1	1	3	0
Other	1	0	1	1	0	0	0	0	0

* TS = Troubleshooting

** The total number of students is less because not all students utilized more than one strategy.

TABLE 35. SECOND IF BOARD - NUMBER OF STUDENTS USING ONE TO FOUR STRATEGIES PRIOR TO FIRST FAULT DIAGNOSIS

TREATMENT CONDITION	STUDENTS USING ONE STRATEGY	TWO STRATEGIES	THREE STRATEGIES	FOUR STRATEGIES*
Troubleshooting CAI	6	5	1	6
Control CAI	4	9	1	4
Control	7	8	1	2

$\chi^2 = 4.00$
$p = .68$
* Includes students using more than four strategies.

TABLE 36. SECOND IF BOARD - SUCCESS RATE BASED ON TOTAL STRATEGIES USED PRIOR TO FIRST FAULT DIAGNOSIS

TREATMENT CONDITION	TOTAL STRATEGIES USED CORRECT FIRST ATTEMPT	INCORRECT FIRST ATTEMPT
Troubleshooting CAI	27	18
Control CAI	26	20
Control	18	15

$\chi^2 = .25$
$p = .88$

TABLE 37. SECOND IF BOARD - SUCCESS RATE OF FIRST DIAGNOSIS USING HALF-SPLIT FIRST VERSUS ALL OTHER STRATEGIES

FIRST STRATEGY USED	CORRECT FIRST ATTEMPT YES	NO
Half-Split	26	19
All Other Strategies	5	3

$\chi^2 = .02$
$p = .88$

TABLE 38. ET COURSE COMPLETION TIME - ANOVA TOTALS (HOURS)

TREATMENT CONDITION	PROFICIENCY LEVEL HIGH	MEDIUM	LOW
Troubleshooting CAI	1693.70	2255.50	2873.40
Control CAI	1676.70	2381.70	3231.10
Control	1582.20	2171.10	2702.10

TABLE 39. ET COURSE COMPLETION TIME - ANOVA SUMMARY

VARIATION SOURCE	SUM OF SQUARES	DEGREES FREEDOM	VARIANCE ESTIMATE	F
Proficiency	412774.00	2	206387.00	94.72**
Treatment	19409.76	2	9704.88	4.45*
Interaction	9823.52	4	2455.88	1.13
Error	98053.20	45	2178.96	
Total	540059.40	53		

** $p < .01$
* $p < .05$

TABLE 40. MEAN COMPLETION TIME BY PROFICIENCY LEVEL

PROFICIENCY LEVEL	MEAN TIME
High	275.14
Medium	378.24
Low	489.26

TABLE 41. MEAN COMPLETION TIME BY TREATMENT CONDITION

TREATMENT CONDITION	MEAN TIME
Troubleshooting CAI	379.03
Control CAI	404.97
Control	358.63

proficiency students completed the course in significantly fewer hours than the medium and low proficiency students and that the medium proficiency students required significantly fewer hours than the low proficiency students ($p<.01$). The LSD post hoc analysis for treatment condition indicated that the baseline control group completed the course in significantly less time than the group receiving the control CAI course ($p<.01$). There was no significant difference in course completion time between the students receiving the troubleshooting CAI course and those receiving no treatment.

STUDENT COMMENTS

The comments made by students on the troubleshooting CAI questionnaire and made to the researcher during the performance tests are summarized and outlined in the following 2 sections.

TROUBLESHOOTING CAI COMMENTS

A Troubleshooting Strategy Questionnaire administered to the 18 experimental treatment subjects, subsequent to their completion of the CAI, indicated the following:

a. Fifteen students felt the CAI unit on Isolation Strategy was the most valuable in helping them learn effective troubleshooting.

b. CAI units on System Flow Visualization, System Visualization and Localization/Fixed Flow gave students the least amount of difficulty.

c. All 18 experimental subjects felt the CAI unit on Feedback was the most difficult.

d. Of the three media used in presenting the experimental treatment condition, all 18 subjects preferred computer interaction; whereas, the least preferred mode of instruction was split between video instruction and the use of a workbook.

PERFORMANCE TEST COMMENTS. The researcher recorded pertinent comments made during the troubleshooting performance tests and the predominant ones are as follows:

a. Learn more in the testing center than in their assigned class.

b. Do not understand how to read a Simpson Multimeter.

c. Prefer using a digital multimeter.

d. Do not understand how to set up the equipment.

e. Do not remember to check front panel symptoms on the trainer.

f. Enjoyed participating in the research performance tests, feel a genuine concern regarding their performance.

g. Feel confused while trying to locate the fault.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

If the troubleshooting CAI used in this research had enhanced the BE&E School's training curriculum, then the students receiving that CAI course should have performed significantly better than the other groups on the performance tests. The research compared treatment and control conditions in a strict experimental environment. Overall, the results indicate that the troubleshooting CAI did not enhance performance, and in some cases, the baseline control group performed significantly better than the troubleshooting CAI group. The statistically significant and non-significant results indicate that the control group receiving no CAI course can perform as well as or better than the groups receiving the CAI treatments.

If the troubleshooting CAI course had given students additional unique instructional material to utilize Half-Split more efficiently, then we would have expected students receiving the troubleshooting CAI to use Half-Split more than the other groups. However, the analysis indicated that all groups initially used the Half-Split technique to localize the fault and that the troubleshooting CAI did not improve strategy usage.

It should be noted that the CAI course resulted in significantly improved performance during the pilot study. At the time of the pilot study, the Half-Split troubleshooting technique was not emphasized in the School. In the time period between completion of the pilot study and initiation of the full study, the School modified the curriculum toward a greater emphasis on the Half-Split troubleshooting technique. With the increased emphasis on the Half-Split technique in the regular curriculum, the CAI course on Half-Split did not lead to improved troubleshooting performance. In fact, the significant ANOVA results indicated negative training effects on the Power Supply board troubleshooting performance. Of the 3 boards, the Power Supply board was the only one with feedback loops. All students receiving the troubleshooting CAI course felt the unit on feedback was the most difficult. The CAI instruction could have interfered with their troubleshooting efficiency if they did not fully comprehend its application.

The logic analysis and review of the performance write-ups indicate that students use essentially the same strategies regardless of additional training. However, review of the logic analysis also indicated that while students may sequentially probe points in a Half-Split pattern, they do not always probe the most logical points. The Half-Split technique requires the user to probe, take a reading, and then make a judgement as to which point will provide information to further localize the fault. Students using this method did not always correctly interpret the information they were gathering.

Missing cues, failure to recognize faults, and the inability to distinguish a good signal from a bad one, were recurring problems. Thus, the Half-Split technique, by itself, did not always lead to the isolation of the fault. This finding could indicate a rote probe sequence rather than a logical usage of meter readings to select the next appropriate point to probe.

The treatment control condition received a BASIC program which should not have affected performance on the troubleshooting tasks. However, data trends indicate that the group receiving the control CAI performed with less efficiency than the other groups. Since the BE&E School is an intensive self-paced program, students in this group may have been affected by removal from the electronic training environment. Removal from the self-paced program should have affected both CAI groups, but the control CAI may have had additional interference from 2-3 days concentrated work on an unrelated new topic.

The hypothesized effect of student proficiency level was supported in the data trends and significant results. As defined within this BE&E School for the research, high proficiency students demonstrate more efficient troubleshooting performance than medium and low proficiency students. The initial proficiency levels set at the beginning of ET Splice can be used to predict performance during the curriculum and to predict course completion times.

In general, the research has indicated that:

a. The off-the-shelf troubleshooting CAI, as used in this research, does not improve student troubleshooting performance. The CAI and School curricula should be reviewed to determine if utilization at another training stage will enhance performance.

b. Review of the curriculum and CAI should be made to determine if a strategic troubleshooting course developed specifically for BE&E School would enhance performance.

c. Review of curriculum and student performance should be made to determine if students understand the Half-Split technique or are probing points by rote memory.

d. Student proficiency level (based on BE&E completion times) can be used to predict performance in ET Splice School. Low proficiency students should be given tutorial assistance to improve their troubleshooting performance.

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GLOSSARY

AET	Actual Equipment Trainer
ANOVA	Analysis of Variance
BE&E	Basic Electricity & Electronics School
CAI	Computer Assisted Instruction
CMI	Computer Managed Instruction
ET	Electronic Technician
First IF	First Intermediate Frequency Board (Medium Complexity)
LS	Learning Supervisor
LSD	Least Significant Difference
Power Supply	Power Supply Board (High Complexity)
Second IF	Second Intermediate Frequency Board (Low Complexity)

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